MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2016/2017

ENT4086 – DIAGNOSTIC TECHNOLOGY

(NE)

18 OCTOBER 2016
02:30 p.m. - 04:30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

(a) Electron Microscopes (EMs) are scientific instruments that use a beam of highly energetic electrons to examine objects on a very fine scale. Describe the basic steps involved in the operation of EMs. [4 marks]

(b) X-Ray Diffraction (XRD) is a structural analytical tool for material investigations.

(i) Describe the operational principles of the XRD. [4 marks]

(ii) Based on a schematic sketch, describe the relationship between wavelength of X-Ray, lattice spacing, and diffraction angle under Bragg's Law. [8 marks]

(c) Auger Emission Spectroscopy (AES) is a failure analysis technique for surface elemental identification. Describe the Auger process in the emission of Auger electrons. [4 marks]

(d) Secondary Ion Mass Spectroscopy (SIMS) is a failure analysis technique used in the compositional analysis of a sample. Discuss the working principles of a SIMS. [5 marks]

QUESTION 2

(a) A Scanning Electron Microscope (SEM) produces images of a sample by scanning it with a focused beam of electrons.

(i) What is the setting range of beam current and scanning speed that is required to increase the contrast of a SEM image? [2 marks]

(ii) Given a SEM coupled with Energy-Dispersive X-Ray Spectroscopy (SEM-EDS), identify the control parameter that will affect the depth of the electron beam penetration. Describe the correlation of this parameter with the penetration depth of the electron beam. [2 marks]

(b) A Scanning Probe Microscopy (SPM) scans an atomically sharp probe over a surface, typically at a distance of a few angstroms or nanometers. The interaction between the sharp probe and surface provides 3-D topographic image of surface at the atomic scale.

(i) Briefly describe THREE common scanning probe techniques applied in the SPM? [3 marks]

(ii) Identify THREE types of operating mode in the SPM technique. Describe the criteria for adopting these operating modes. [6 marks]

(iii) With schematics aid, describe TWO factors influencing the resolution of the SPM. [4 marks]

(c) AES is a common analytical technique employed in the study of surfaces. However, Hydrogen and Helium atoms are undetectable by AES. Explain the rationale for this limitation with AES. [2 marks]

(d) The yield of secondary ion sputtering, which affects SIMS sensitivity, depends on the nature of the primary beam of ions. The proper choice of primary ion beam is therefore important in enhancing the sensitivity of SIMS. Describe the role of the oxygen, cesium, and liquid metal ion as primary beam of ions source in the application of SIMS. [6 marks]

QUESTION 3

(a) **Figure 3(a)** shows an SEM image for silica coated nanorods grown on a glass substrate impregnated with gold nanorods.

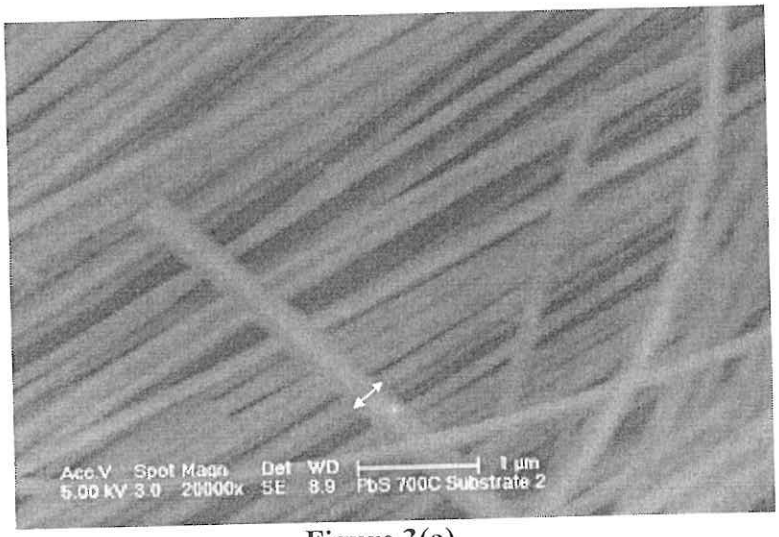


Figure 3(a)

(i) Determine the diameter of the nanorod highlighted with arrow in the SEM image. [1 mark]

(ii) Determine the magnification, acceleration voltage, working distance and the spot size adopted in the SEM imaging setting as shown in **Figure 3(a)**. [2 marks]

(b) The full width at half maximum (FWHM) for the measured XRD spectra are 0.133° and 0.155°, respectively. The 2-theta degree is at 35° for these two XRD spectra, the shape factor of the average crystallite size is 0.9, and the employed X-Ray wavelength is 0.154 nm.

(i) Calculate the crystallite sizes for the measured spectra using Scherrer's formula. [7 marks]

(ii) Which XRD spectrum exhibits a lower crystallite size? [1 mark]

QUESTION 3

(c) **Figure 3(c)** shows the X-Ray Fluorescence (XRF) spectrum of nanocomposites of sputtered titanium oxide film on graphene oxide nanosheets. Analyze the spectrum in terms of peaks observed, relative concentrations of constituent materials, and layer analyzed, respectively. [7 marks]

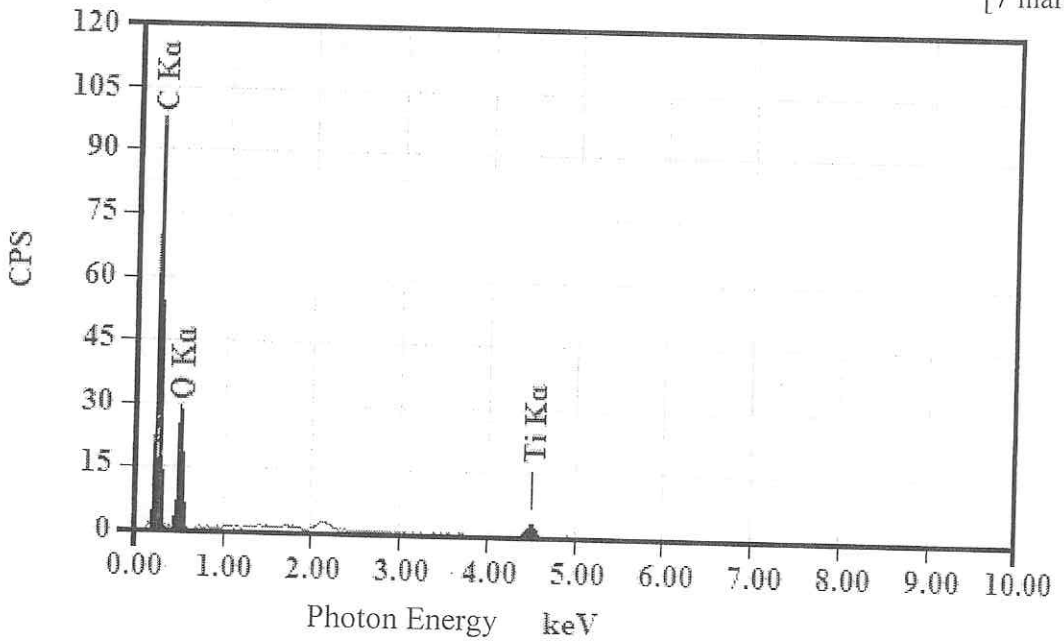


Figure 3(c)

(d) **Figure 3(d)** shows the SIMS depth profile of a shallow silicon (Si) PN junction. Both Arsenic (As) and Boron (B) were measured with 2 keV ions at 60° incidence. Determine the depth of the PN junction. [3 marks]

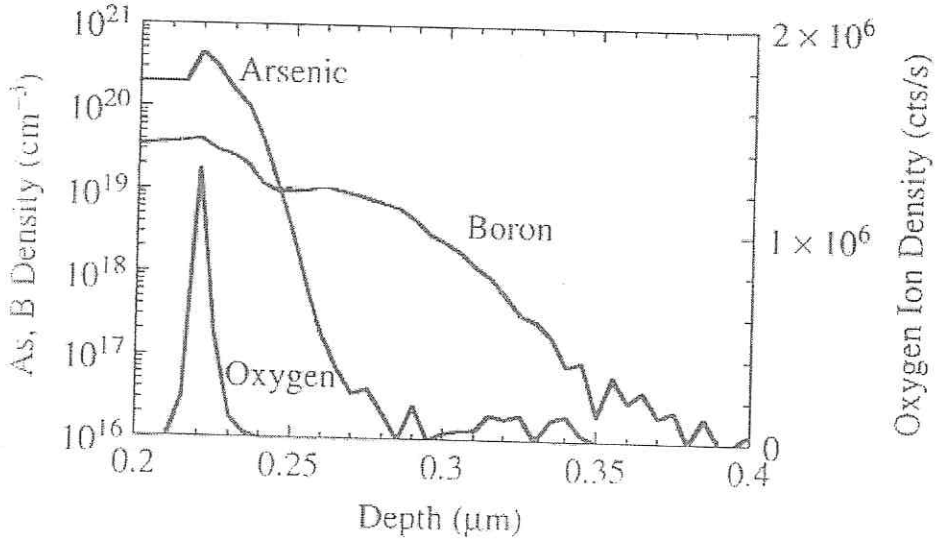


Figure 3(d)

QUESTION 3

(e) The depth profile of a trilayer structure (top, intermediate and bottom layers) coated on iron-carbon alloy plate measured with a SIMS is given in **Figure 3(e)**. Analyze the spectra of the intermediate and bottom layers in terms of the constituent materials and the thickness of each layer. (*Note: O and Ar are impurities*). [4 marks]

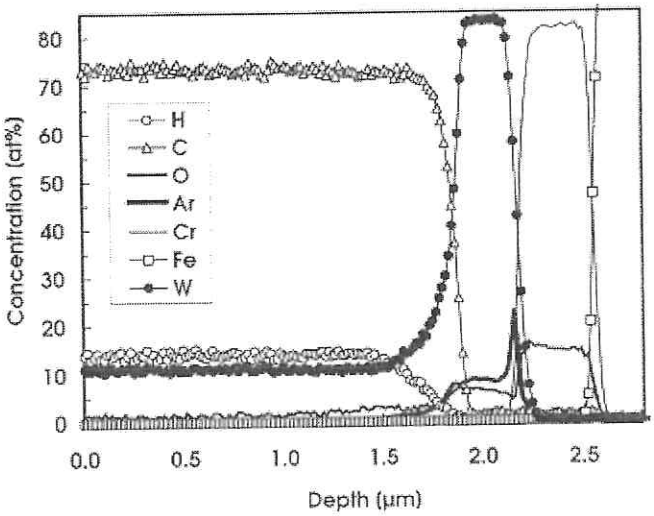
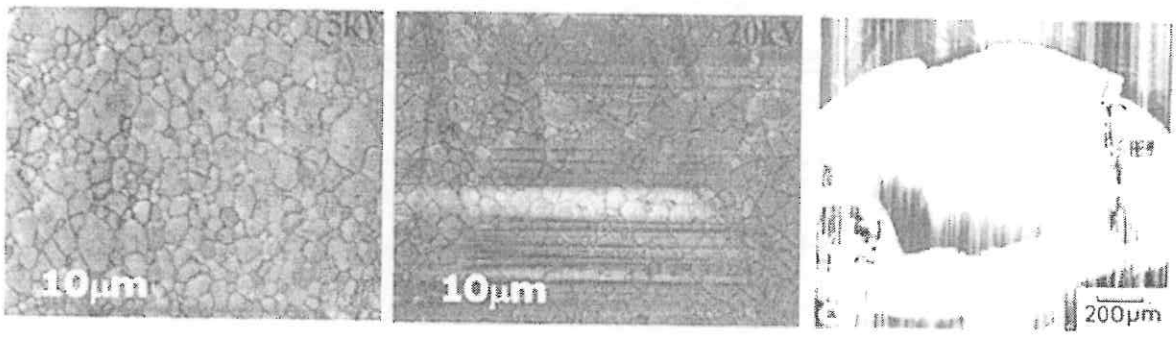


Figure 3(e)

QUESTION 4

(a) **Figure 4(a)** shows the SEM images for thermally etched polycrystalline alumina, recorded by using acceleration voltage of 5 kV electrons, 20 kV electrons, and 30 kV electrons. No conductive coating was applied to the specimen, which is non conducting in nature. Identify which acceleration voltage results in SEM image given in **Figures 4(a)(i)**, **(ii)**, and **(iii)**, respectively. Describe the reason why the quality of the SEM images in **Figure 4(a)** varies with different acceleration voltage. [7 marks]



(i) **(ii)** **(iii)**

Figure 4(a)

(b) The Transmission Electron Microscopy (TEM) images of silver nanoparticles dispersed on substrates are as shown in **Figures 4(b)(i)** and **4(b)(ii)**, respectively.

(i) Differentiate the bright-field (BF) and dark-field (DF) image formation mechanisms in TEM. [2 marks]

(ii) Identify the type of the image (BF or DF) for the **Figures 4(b)(i)** and **4(b)(ii)**, respectively. [2 marks]

(iii) Estimate the average diameter size of the silver nanoparticle based on the observation from the TEM images in **Figures 4(b)(i)** and **4(b)(ii)**. [2 marks]

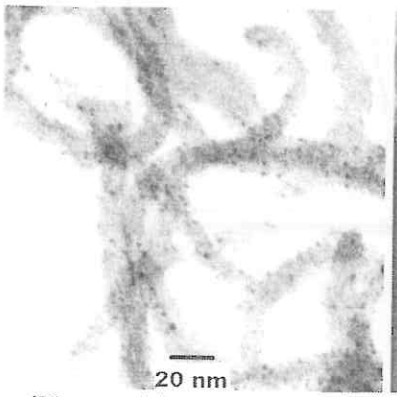


Figure 4(b)(i)

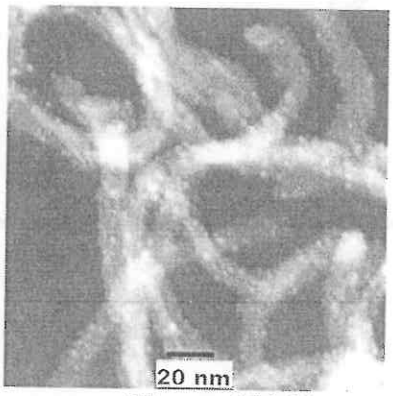


Figure 4(b)(ii)

QUESTION 4

(c) (i) Describe the criteria adopted in identifying an amorphous and crystalline material based on XRD analysis. [4 marks]

(ii) Determine whether the measured XRD spectrum in **Figure 4(c)** is crystalline or amorphous. [2 marks]

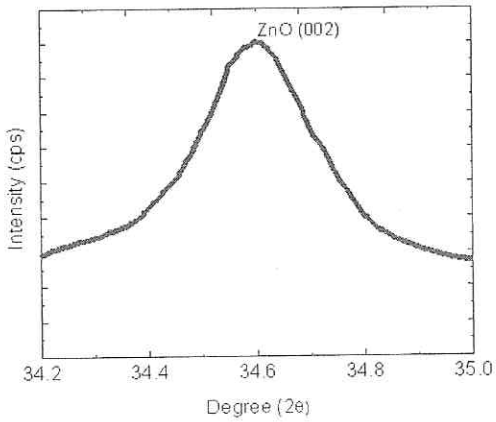


Figure 4(c)

(d) **Figure 4(d)** shows the Auger depth profile of a silicon oxide (SiO_2) film on silicon (Si). Determine the thickness of the SiO_2 film. Which Auger signal corresponds to oxygen and which Auger signal corresponds to silicon in **Figure 4(d)**? Explain the rationale. [6 marks]

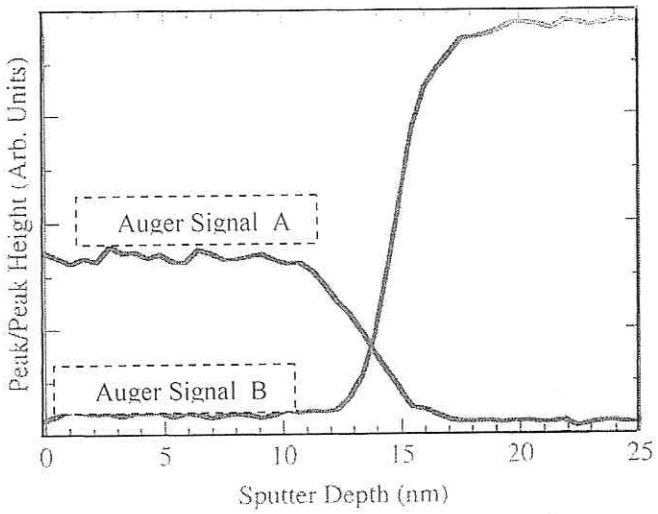


Figure 4(d)

End of Paper